read his paper here. I made guns in March, 1855; he talked of them in June of the same year.

FURTHER REMARKS BY DR. HART.

A question of priority having arisen, and Captain Blakely having referred to a letter of Dr. Hart to him, in which he mentioned 1855 as the date of his investigations, Dr. Hart replied, that he had not intended to raise any question of priority; that in the letter referred to, he had said that he believed his investigations and Captain Blakely's had been simultaneous, as they were certainly independent, and that he had preserved no record of dates; but that Mr. Mallet, being in possession of the original letters which contained his calculations, could supply them if they were considered important. The fact was, that Captain Blakely's investigations were experimental, and resulted in a gun; Dr. Hart's were mathematical, and resulted in a formula. Both are presumed to be original; at all events they were distinct, and the question of priority or synchronism seems perfectly immaterial.

MONDAY, MAY 28, 1860.

GILBERT SANDERS, Esq., in the Chair.

MR. GEORGE J. STONEY read a paper "On the Propagation of Waves."

MR. DAVID MOORE, Curator of the Royal Dublin Society's Botanic Garden, Glasnevin, read the following—

RESULTS OF FARTHER PHYSIOLOGICAL EXPERIMENTS ON THE FORMATION OF WOOD IN DICOTYLEDONOUS PLANTS, MADE IN THE ROYAL DUBLIN SOCIETY'S BOTANIC GARDEN BETWEEN THE YEARS 1851 AND 1860.

IN the year 1851 I had the honour to make known to the Academy the results of a series of physiological experiments which had then been made in the Botanic Garden, with a view to ascertain the nature of the formation of wood in dicotyledonous plants, which I detailed in a paper published in the "Proceedings" of the Academy, vol. v. p. 1. Those experiments had extended over twelve years (from 1839 to 1851), and were only in a progressive state at the time the paper was read. The object of the present communication is, therefore, to state some further results, which have been ascertained since that time, and also to notice other experiments of a different kind, though made for the same purpose, during the interval between 1851 and 1860.

On reference to the paper I have alluded to, it will be found the principal experiment made was on the bole of a large tree, nearly five feet in circumference, which was bored at right angles through the centre, each bore being seven inches wide,—thus occupying half the space of the circumference of the tree, which was then left standing on four pillars of wood, occupying the other half. The whole of the wood portion soon became dead, and served only the purpose of acting as supports for the bole, without any of the functions of vitality being carried on through its medium: consequently, the bark covering the pillars of dead wood were the only parts in that portion of the tree where

these functions could take place. They in turn were denuded of their bark covering, one after the other, at intervals, according as the newly formed wood on the pillar first laid bare had made a junction with the lower lip of the cut, thus keeping up communication for the circulation of the sap. In this way every organ of the tree, over nearly a foot of its bole, was destroyed and again renewed, without killing it, or even arresting growth to any visible extent. It continued to unfold its leaves at the proper season, and produce new wood as other trees of the same kind did, with this difference only, that about four feet of the apex of the stem died.

My object in continuing the experiment was two-fold:—First, to prove whether the tree would continue to live; and, if so, whether any visible effects on its growth would result. Secondly, to ascertain, if possible, how far the wood continued dead towards the apex of the bole from the spot where the operation took place.

With respect to the former, I can now state that the wounded portion of the stem is nearly healed over, with the exception of one hole, about two inches wide, which is partly filled with the debris of the decaying wood, and out of which moisture constantly oozes; but otherwise the tree is quite healthy, and the only visible effect produced by the mutilation is, that of causing it to leaf and flower a little earlier than other trees of the same kind near it do. I could not ascertain the second object without destroying the tree, which would have defeated the first,—consequently, similar experiments had to be made on other trees, the results of which I now proceed to lay before the Academy. The figures in Nos. 1 *a* and *b* of the diagrams correspond with the specimens operated on, and now on the table, which are transverse sections, cut at

No. 1 *a*. No. 1 *b*.

different heights above the place where the borings were made through the bole. No. 1 *b* was cut 5 feet above it, and where the dead wood had greatly decreased in diameter, but it continued so, still farther decreasing 3 feet higher up the stem, where it commingled with

living tissue, and at 10 feet disappeared altogether, after which the remaining portion of the stem was healthy, having pith and wood layers regularly formed. Such has the remarkable permeability of vegetable tissue been proved to be, that every organ of a large tree has been killed over a space of nearly eight inches in the centre of its stem without killing the plant, or impeding the circulation of sap to any great extent; and although the wood portion so destroyed continued dead through a space of ten feet, it was again renewed to living tissue through the remaining portion of the stem—every organ in regular order.

No. 2 diagram corresponds with specimens on the table, which were operated on for the purpose of showing how wood is formed when a growing branch is isolated on the stem of a tree. A similar experiment had been commenced by Mr. N. Niven before he left the Garden, but sufficient time had not elapsed for its completion.

The present specimens have been under operation during the last seven years, and prove more incontestably what has long been held as an axiom in vegetable physiology, namely, that the principal formation of new wood in dicotyledonous plants takes place in a downward direction, from the apex to the base of the stem. It was in consequence of Dr. Schleiden, of Jena, impugning this theory, so lately as within the last ten years, that I was desirous to prove or disprove it. In my former paper I was inclined to adopt his views on this matter, to some extent, which further experience has shown me are erroneous. But his investigations on the origin of vegetable tissues, and his excellent definition of the true distinctions between the formation of the stems of monocotyledonous and dicotyledonous plants, are such as to claim for any theory he holds on this subject profound respect. Both he and Dr. Mohl have, through recent investigations, clearly proved that the vascular bundles of tissue which, combined, form so large a portion of the solid wood, grow in an upward direction, and enter the leaves from below upwards, which is the converse of the theory so long held by Du Petit Thouars and his followers, that the vascular bundles were prolongations from the bases of the leaves downwards to the roots; hence they accounted for the increase of wood taking place in a vertical direction. But all my specimens show that the new formation takes place in a horizontal plane from the axis, as well as it does in a vertical, thus proving that it is the alteration of tissue in the cambium layer towards the periphery of the stem which causes the increase in girth, and not so much owing to the growth of tissue downwards.

No. 2.

At this point, I am led to refer to an article on sap circulation in plants by M. Trecul, published in "Comptes Rendus," September,

1857, page 434, which, so far as I can judge, is a most able exposition. The author expresses his belief in a double circulation, or, in other words, a rise and descent of the sap, which he calls the great circulation, and also in a secondary or smaller circulation through the lactiferous vessels, which he calls the venous circulation. He further argues against the probability, amounting almost to impossibility, of the physical actions of endosmose and capillarity playing so important a part in sap circulation as they have been so generally believed to do by physiologists. But what chiefly concerns my present subject is, his account of the manner descending sap acts in forming the tissues which constitute wood. To quote a paragraph from M. Trecul's paper will enable me to make his views on the matter better understood than anything I can state, viz.:—"The sap, which on its way takes part in the nutrition of the organs first developed, arrives in the leaves, in the green parenchyma of which it is submitted to fresh elaboration, or in the chlorophyl cells of the stems of fleshy plants without leaves. The carbonic acid of the air is absorbed, and then decomposed during the day; its carbon is retained by the sap, and its oxygen is in great part rejected. The sap, thus modified under the influence of respiration, takes its course through the cortical cells, which it nourishes. It then aids in the multiplication of the cells of the generative layer, which are produced in horizontal series. A portion of these cells, thus horizontally multiplied, forms a new layer of bark, the woody fibres and medullary rays; the others are converted into vessels in the following manner—the excess of the descending sap, which is not employed in the nutrition of the newly formed cells, or in thickening those first developed, descends through certain of the newly-formed cells, it dilates them, perforates them, and makes them take all the characters of vessels, so that those cells which, during the first phase of their developement, resembled all the others, appear subsequently to be of a totally different nature." Now this appears to me to be a succinct statement of the true theory of the formation of vascular tissues in exogenous plants, one which all my experiments agree with, and that on which the circumstance of stocks on which plants are grafted not being covered with layers of the wood of the graft united to them, can be easily demonstrated.

The specimens agreeing with diagram No. 3 were denuded of their bark, and had also the cambium layer scraped off; yet they have continued to grow during the last six years, and the parts denuded have increased slightly in circumference, though much slower than the portions, on

No. 3.

which the bark is, have done. They prove against the descending circulation being solely confined to the bark layers, and show that it possesses the power of diverging into the layers of young wood until it passes the decorticated parts; as much of it, at least, as enables the vital functions to be supported: but, no doubt, a great arrest of it takes place on the upper lip of the cut, or point of divergence from the bark cells to those of the cambium.

There is, however, one important feature exhibited by those specimens, and also by those of diagram No. 2, namely, wherever the upward flow of sap has been arrested, adventitious buds have formed and produced branches. It would thus appear that the peculiar kind of cells or lenticels, which form the basis of those elongating axes, are nourished and produced by the ascending sap, but whether that be truly the case, remains uncertain. The arrest of the upward flow of sap, and consequent greater accumulation of it at the lower lip of the cut, may cause a partial descent to take place, and thus give rise to the adventitious bud cells, but, certainly, I have never seen them produced above the upper lip of a partially decorticated stem, where roots will be produced if preparations be made to secure moisture and exclude light.

No. 4.

The specimens agreeing with diagram No. 4 are curious. No. 4 *a* is a portion of the branch of a weeping beech, which grew in a nearly downward vertical position from the bole of the tree to the earth, and was operated on to prove whether the denser sap would be affected by gravitation. It will, however, be seen, on examining the specimen, that this power has had very little influence. The newly formed tissue has increased for the most part in a vertical position from the apex to the

base of the branch, though in this case growing upwards, in consequence of the position of the branch being reversed.

No. 4 *b* is part of the stem of a holly-tree, which stood in its natural position when operated on. It shows, also, that the principal portions of newly formed wood have grown chiefly on the upper lips of the spiral denudations.

No. 4 *c* is part of a branch which grew as nearly as possible in a horizontal position from the axis of the tree. It was denuded of bark over the upper half of its circumference, the bark on the lower half next the earth being still attached. The cells forming woody tissues in this instance have been produced for the most part in horizontal series, having little preponderance to the part nearest the base of the branch, which favours the correctness of M. Trecul's views, as stated above.

I have now, in this and a former paper, laid before the Academy the results, such as they are, of twenty years' experiments on this subject, which may appear a long period; but we cannot force the operations of nature, and must, therefore, be content to wait assiduously on her if we desire to elicit trustworthy data, such as can be useful to future students following in the same path of investigations.

SIR WILLIAM ROWAN HAMILTON, LL.D., M.R.I.A., read the following paragraphs in continuation of his paper—

ON ANHARMONIC CO-ORDINATES.

11. To myself it naturally appears as a *fourth advantage* of the anharmonic method, that it is found to harmonize well with the method of *quaternions*, and was in fact *suggested* thereby; though not without suggestions from other methods previously known.

12. Thus, if α, β, γ denote three given vectors, OA, OB, OC, from a given origin O, while a, b, c are three given and constant scalars, but t, u, v are three variable scalars, subject to the condition that their sum is zero,

$$t + a + v = 0\,;$$

then the equation,

$$\mathrm{OP} = \rho = \frac{t^r a\alpha + u^r b\beta + v^r c\gamma}{t^r a + u^r b + v^r c},$$

in which r is any positive and whole exponent, expresses generally that the *locus* of the point P is a *curve of the r^{th} order*, in the given plane of ABC; which curve has the property, that it is met in r coincident points, by any one of the three sides of the given triangle ABC. But the coefficients t^r u^r v^r are examples here of what have been above called anharmonic co-ordinates.

CAPTAIN BLAKELY read the following:—

CAPTAIN BLAKELY'S REMARKS IN CONTINUATION OF HIS REPLY TO MR. MALLET AT THE MEETING OF THE ROYAL IRISH ACADEMY ON MAY 14, 1860.

MR. CHAIRMAN,—At the last meeting of the Academy a question was raised by Mr. Mallet, between himself, Dr. Hart, and me, as to which